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MEMORANDUM ON LABORATORY RECORDS

MAY TO DECEMBER, 1935

# CRITICAL LOW TEMPERATURES FOR THE WESTERN PINE AND MOUNTAIN PINE BEETLES

by
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Berkeley, California
January 13, 1936

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Forest Insect Laboratory
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# CRITICAL LOW TEMPERATURES FOR THE WESTERN PINE AND MOUNTAIN PINE BEETLES

## WESTERN PINE BEETLE STUDIES

The work presented in this memorandum is a continuation of that previously reported by Miller and Struble, and by the writer, in which most of the effort had been applied to the study of the critical range of Dendroctonus brevicomis. It was found, however, that D. monticolae was much more responsive to changes in external conditions, so this species has received the greater attention in recent months. Those tests which were made on the western pine beetle during this period were incidental and are therefore quite incomplete.

The methods employed were the same as those given in the previous reports, except the larvae were not pre-chilled at 36° or carried slowly down through the temperatures above the critical range. The cabinet was set at the desired temperature, the larvae then introduced and given a two hour exposure, each successive sample of larvae being tested in this manner.

The results, presented in Figure 1 and the appendix, indicate that the northern California larvae are more resistant than those from the central Sierra and that resistance increases with the advent of winter conditions.

One very interesting point was the mortality in the winter brood larvae in the field as a result of a sudden cold snap affecting the Modoc during the fall of 1935. The infested bark collected for laboratory material was removed from the trees November 1, and stored out-of-doors at Hackamore until November 5. During this period extreme weather conditions occurred, the temperature dropping for a time to approximately -3°F. This resulted in a high mortality (about 50%) of the larvae in the bark which had been collected and stored for the laboratory tests. Unfortunately, no examination was made to determine whether the larvae in bark remaining on the trees had suffered equally. However, this observation is in direct accord with that made by Furniss on larvae affected by the same cold spell in the Ochoco National Forest. This indicates that a moderately cold spell coming early in the winter before the larvae are prepared for extremes of temperature may be a much greater factor in natural control than would a period of colder weather arriving after the larvae had developed their maximum resistance.

## MOUNTAIN PINE BEETLE STUDIES

The methods used in these studies were improvements over those previously used, both in securing material, transporting it to the laboratory, and in making the exposures.

It was found in previous experimental work that dependence upon material that could be found in standing trees was often unsatisfactory. Suitable broods could not always be found in the desired host trees at convenient points. For this reason plans were made in 1935 to develope thru cage control the greater part of the material needed.

Cage rearings were made by Struble at the central Sierra field Station near Wawona, California, in connection with host selection studies, and three hosts, sugar pine, ponderosa pine and lodgepole pine each rearing parent adults from a known host were forced on the three hosts; sugar pine, lodgepole pine, and ponderosa pine so that any possible difference due to host races could be eliminated.

At the end of the field season all the material which had not been used was stored out-of-doors in a protected spot and at an elevation of 6000 feet at Chinquapin Ranger Station in the Yosemite National Park. The material was brought to the Berkeley Laboratory by truck as needed. Only one day was required for the trip and during the summer and early fall months precautions were taken to do all traveling either in cool weather, or at night so that the higher temperatures of the San Joaquin Valley would not be a factor.

As in the past, the larvae were prepared for testing.by removing them from the logs and placing in paraffin cells. Exposures were then made as soon as possible, for it was found that the larvae of this species become sufficiently weakened to give misleading results soon after they are removed from the host.

All exposures to critical temperatures were for a period of 2 hours plus 15 minutes for cooling of containers. Specific tests have shown this to be an adequate interval for testing the effects of critical low temperatures.

The following figures and accompanying explanations present the recent findings.

Figure 2 indicates the effect of host on the cold hardiness of the larvae and indicates that the nutrition may be ultimate factor concerned in as much as the larvae from sugar pine not only had less resistance in each case but were also found to develop more slowly. It would be most interesting to continue this phase of the work.

Figure 3 shows that cold hardiness can be developed by exposing the larvae to temperatures above the critical range. The fact that the larvae that were held at $20^{\circ}$ developed less resistance than those held at $36^{\circ}$ seems rather odd. However, a probable explanation suggests itself: it may have been that the sudden and prolonged subjection to $20^{\circ}$ reduced metabolic activity to such a low rate that the physiological changes involved attaining a resistant state could not take place in as great a number of individuals as was possible at $36^{\circ}$. It is earnestly hoped that it will be possible to give considerably more attention to this most interesting phase of the work.

Figure 4 shows the difference in cold resistance between larvae from different localities and again definitely demonstrates that larvae from a colder climate have a greater cold resistance. The next step now will be to secure parent adults from both the Klamath or other northern region and from the same host in the central Sierra, and then to secure progeny from both to determine whether the greater cold hardiness of the northern individuals are transmitted to a succeeding generation when the stress of cold weather is removed.

WESTERN PINE BEETLE

Comparison of Cold Resistance of Summer and Winter Brood Larvae from Central Sierra and Modoc Regions

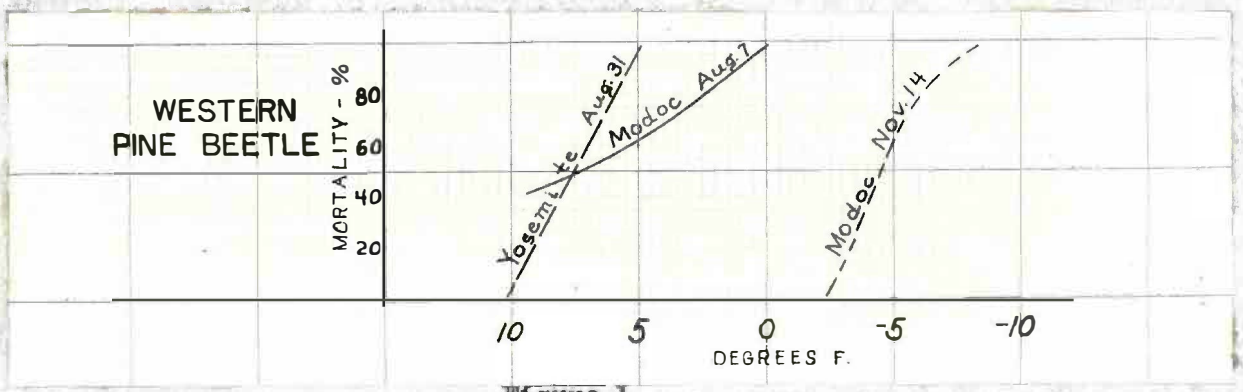


Figure 1

Dates shown on each curve are the dates on which tests were made at the Berkeley Laboratory from material brought in from the field, just preceeding the test. The cold resistance shown by each curve represents the natural cold hardiness developed in the field up to that date. The test made August 7 was for summer brood larvae brought down from Modoc National Forest and shows a killing range extending down to 0°F. The second test, August 31, was on summer brood larvae from Yosemite National Park. These larvae were considerably less resistant than those from the northern region, critical range 10° to 5°. Both have a critical range higher than those for tests run in 1934. The reason for this difference is not known.

Additional material from Modoc was tested November 14. This brood was in the process of going into the winter condition, but a sudden cold snap came before the larvae were fully prepared and many died in the field. Those individuals that were tested were survivors of the cold period and hence constituted a select group. This then accounts for the narrow critical range, -3° to -7½°F, indicated in the graph, as those which would have succumbed at higher temperatures had already been eliminated. A very wide difference between the cold hardiness of summer and winter broods is also brought out by comparing the curve of this winter test with that of August 7.

**Critical Temperatures Affecting Larvae in Relation to Host Trees**

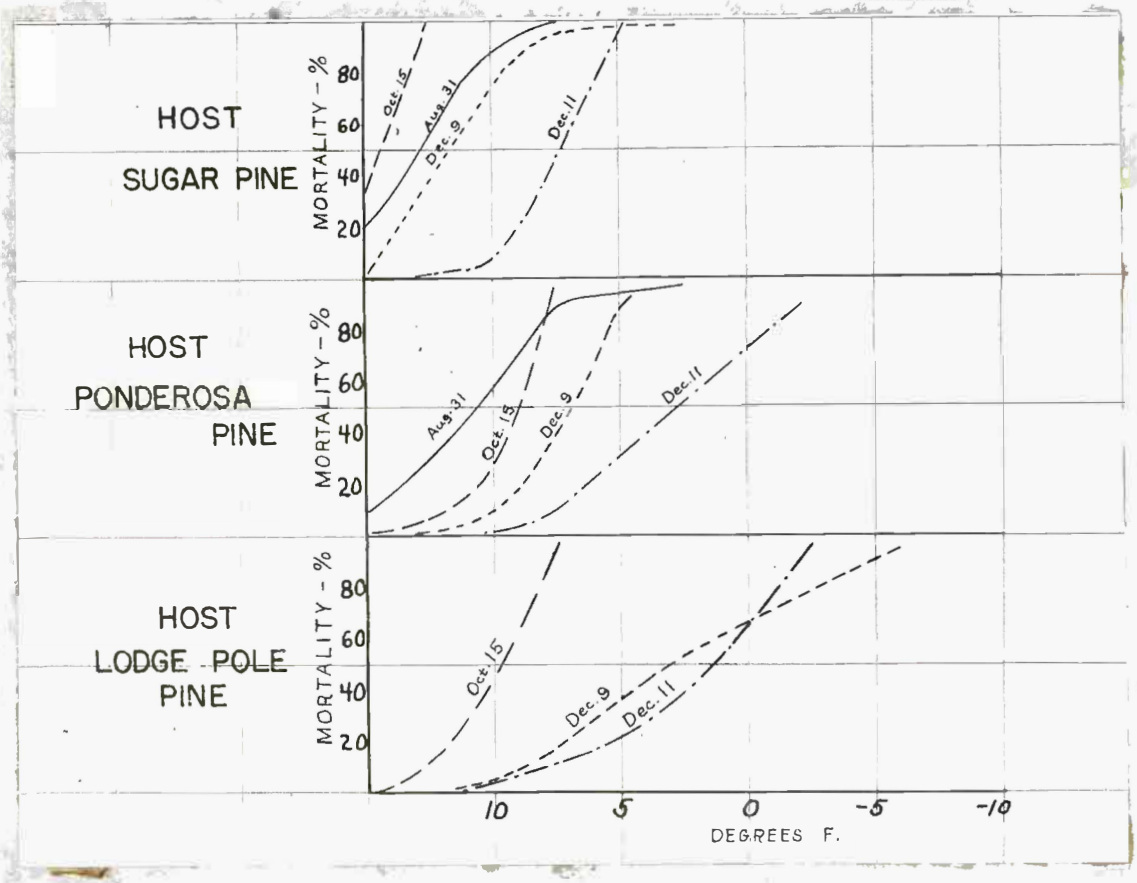


**Figure 2**

The primary object was to discover what effect different hosts would have upon the cold resistance of the brood. With this in mind, groups of parent adults from lodgepole and sugar pine each were forced on sugar pine, ponderosa pine, and lodgepole pine, the brood allowed to develop and then tested when one-half to full grown. The rearing was so conducted that each test included only the progeny of parent adults from a single host from one locality. For example, in the test made October 15, the brood in all three hosts were the offspring of a group of parent adults which had emerged from lodgepole pine in the central Sierra locality. The attack of the parents, the rearing and exposure of larvae for the components of each test were made simultaneously under identical conditions.

In this host comparison both summer and winter condition of the broods were included in the tests. The graphs of these results bring out two points:

1. Differences due to seasonal changes. As the fall season progressed the larvae became more resistant; considering, for example, the larvae reared in ponderosa pine, those exposed on October 15 had a critical range of roughly 15° to $7\frac{1}{2}^{\circ}$, whereas those tested December 9 indicated a killing range of from $12\frac{1}{2}^{\circ}$ to $-2\frac{1}{2}^{\circ}$F. Similar trends are shown for larvae from the other hosts, the one inconsistency being the test made on August 31, in which the larvae from sugar pine and ponderosa pine were more resistant than the larvae in the comparative tests made on October 15. It should be mentioned that the difference between the December 9 and December 11 tests was that the material for both was brought in at the same time and the latter was stored at 36° for three days and may have acquired additional hardening in that time.

2. Differences due to host conditions. The most important difference found is that for each test involving larvae from the three hosts, those from sugar pine are much less resistant than those from either ponderosa pine or lodgepole pine. For example, in the material tested October 15, the larvae from sugar pine all succumbed at $12\frac{1}{2}^{\circ}$, but the larvae from ponderosa pine and lodgepole pine were not all killed until the temperature was reduced to $7\frac{1}{2}^{\circ}$. Similarly, in the test of December 11, the sugar pine larvae had a critical range from $12\frac{1}{2}$ to 5°, whereas the larvae from sugar pine and lodgepole pine had some survivors at $-2\frac{1}{2}^{\circ}$. There seems to be little difference between the resistance of larvae from ponderosa pine and lodgepole pine, although further tests may bring out a difference.

MOUNTAIN PINE BEETLE

The Effect of Previous Conditioning of Larvae on the Critical Range

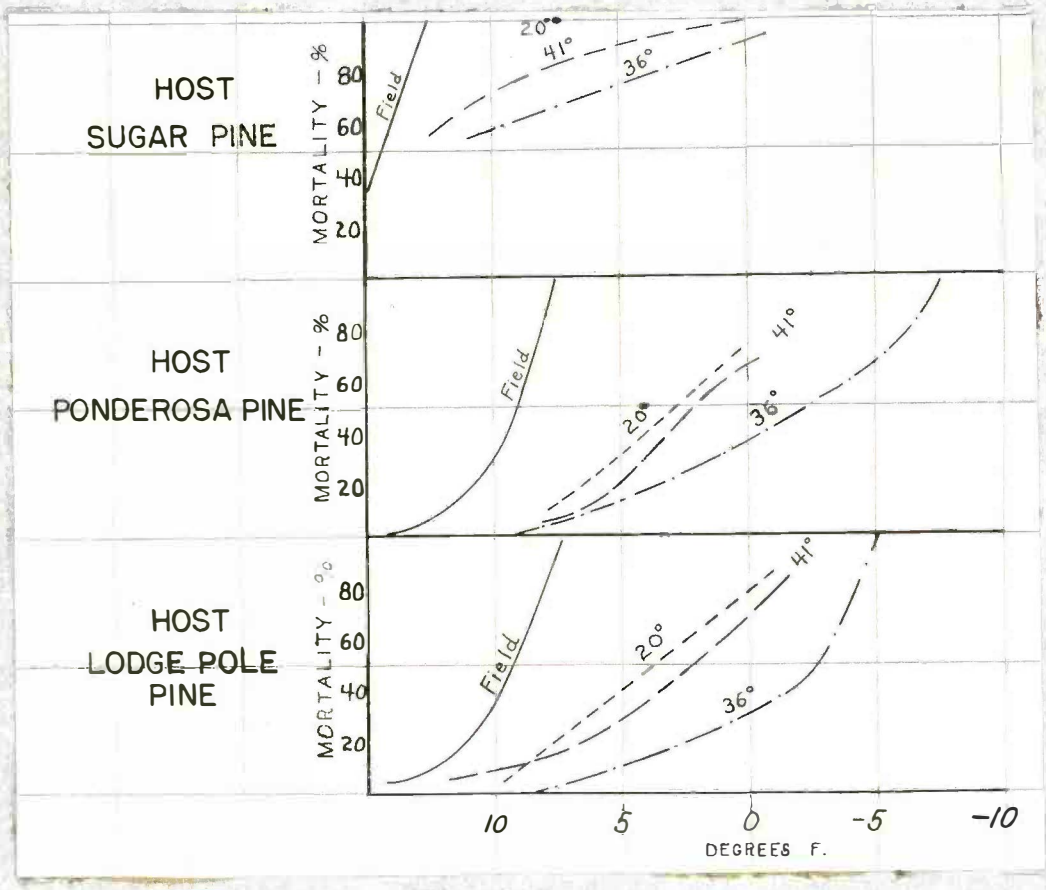


Figure 3

The larvae in all three hosts used in this series of tests were the progeny of parent adults which had emerged from lodgepole pine in the central Sierra region. All larvae were in the active summer condition when brought in from the field and in making tests one-half to full grown larvae were used. The logs containing these larvae were divided into four groups each of which contained representatives of each host. From one portion the larvae were removed at once and tested. The others were placed at 41° , 36° and 20° respectively for approximately seven weeks, after which the larvae were tested to determine what change in resistance had taken place. The rearing and testing of all groups were done under identical conditions.

The results show that prolonged subjection to temperatures near freezing considerably increase cold hardiness. The larvae as they came in from the field (designated by Field on the curve) were all killed at relatively high temperatures - 12½° for sugar pine larvae and 7½° for ponderosa pine and lodgepole pine larvae. The larvae placed at 36° showed the most resistance; the sugar pine larvae enduring 0° , those from

ponderosa pine surviving down to $-7\frac{1}{2}^{0}$ and those from lodgepole pine down to $-5^{0}$. The lot held at $41^{0}$ was next in order of resistance, the sugar pine larvae surviving down to $0^{0}$ and the ponderosa and lodgepole groups enduring $0^{0}$ and possibly would have withstood $-2\frac{1}{2}^{0}$ had there been sufficient material. Those larvae held at $20^{0}$ were less resistant than the $41^{0}$ group and many died during the conditioning period. The few sugar pine larvae tested all died at $7\frac{1}{2}^{0}$. The ponderosa pine and lodgepole pine groups withstood $0^{0}$ as did the similar groups conditioned at $41^{0}$, but showed a greater mortality than did the $41^{0}$ at this same point.

It might also be mentioned that there was a surplus of the lodgepole pine material used in the test of December 9 shown in Figure 2. This surplus log was placed at $36^{0}$ for one week and then the larvae were removed to be used to determine the effect of prolonged exposure at $0^{0}$. The test was not a success, because the resistance of the larvae had so increased that all survived a 24-hour exposure at $0^{0}$.

These results definitely show that summer brood larvae may be rendered more hardy by subjection to temperatures near freezing. The curves also indicate that there is a certain optimum temperature above or below which conditioning becomes less effective.

MOUNTAIN PINE BEETLE

Critical Temperatures Affecting Larvae in Relation to Locality

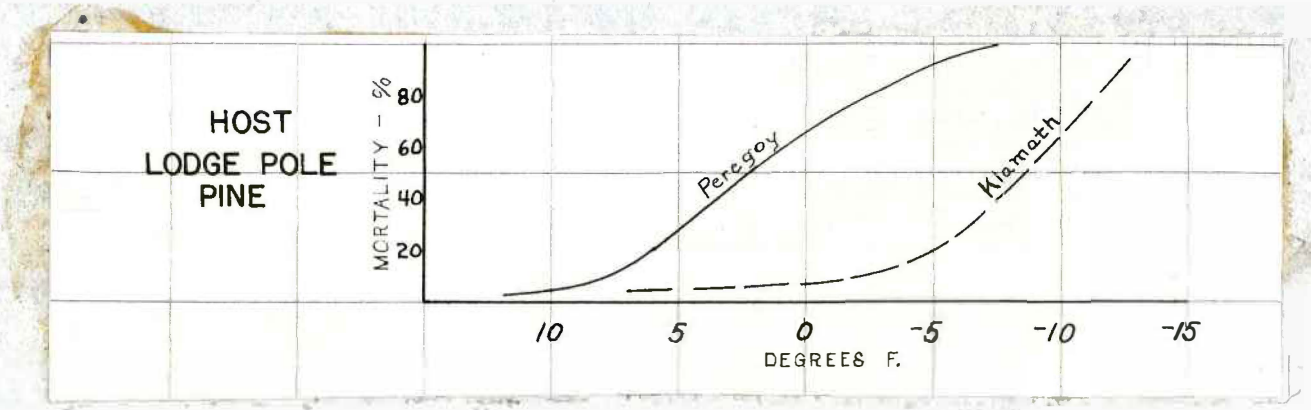


Figure 4

The purpose of this experiment was to compare the resistance of larvae in lodgepole pine from the central Sierra region (Peregoy - Yosemite National Park) with larvae in the same host from the colder Klamath region of Oregon. To this end, infested logs from both regions were stored together for about six weeks in the central Sierra and were then brought to Berkeley and the half to full grown larvae were tested. This brood was in the winter condition when tested. The curves illustrate very definitely the difference in cold hardiness; some of the Klamath larvae were able to withstand $-12\frac{1}{2}^{\circ}$ as compared to a minimum of approximately $-5^{\circ}$ for the Peregoy material.

## APPENDIX

## WESTERN PINE BEETLE STUDIES

Test No. 27 of Laboratory Notes
August 7, 1935

Material and Procedure: Infested bark from Modoc National Forest brought to Berkeley by truck July 31 and stored in shade out-of-doors. Larvae removed from bark August 7 and exposed at once. Samples of brood in bark were also exposed for a period of 8 hours. These larvae were small rat tails.

Results:

| | Naked Larvae | | Bark Samples | |
|---|---|---|---|---|
| Temperature | No. Larvae in Sample | Mortality % | No. Larvae in Sample | Mortality % |
| Check | 50 | 0 | | |
| 10° | 50 | 52 | 27 | 4 |
| 7½° | 50 | 48 | | |
| 5° | 50 | 60 | | |
| 2½° | 50 | 84 | | |
| 0° | 50 | 92 | 78 | 99 |

Test No. 29 of Laboratory Notes
August 31, 1935

Material and Procedure: Infested bark collected in Yosemite National Park and brought to Berkeley by truck August 27. Exposed August 29. Bark samples exposed 8 hours August 31 and analyzed September 9.

Results:

| | Naked Larvae | | Bark Samples | |
|---|---|---|---|---|
| Temperature | No. Larvae in Sample | Mortality % | No. Larvae in Sample | Mortality % |
| Check | 48 | 6 | | |
| 10° | 48 | 4 | 51 | 17 |
| 7½° | 50 | 50 | 50 | 100 |
| 5° | 50 | 96 | 50 | 100 |
| 3° | 50 | 100 | | |
| 2° | 50 | 100 | | |

Test No. 36 of Laboratory Notes
November 13 and 14, 1935

Material and Procedure: Infested bark was removed from the trees November 1 and piled out-of-doors at Hackamore until November 5. During this period a sudden cold snap occurred in which the temperature dropped to approximately -3° F. The bark was brought to Berkeley by truck

November 5, stored at 36 until removed from the bark and exposed November 13. When removing the larvae from the bark it was found that a considerable number of them had been killed by the cold weather in the field.

Results:

| Temperature | No. Larvae in Sample | Mortality % |
|---|---|---|
| Check | 50 | 2 |
| 10 | 50 | 0 |
| 7½ | 50 | 4 |
| 5 | 50 | 0 |
| 2½ | 50 | 0 |
| 0 | 50 | 0 |
| -2½ | 50 | 4 |
| -5 | 50 | 62 |
| -7½ | 50 | 94 |
| -10 | 50 | 100 |

## MOUNTAIN PINE BEETLE STUDIES

### Length of Exposure and Mortality

Test No. 33 and 34 of Laboratory Notes
October 19 and November 1, 1935

Material and Procedure: No. 33 - summer brood in ponderosa pine brought to Berkeley August 30 and stored out-of-doors until October 18 late in the day when larvae were removed from the log. Exposures made October 19. No. 34 - brood in sugar pine brought to Berkeley October 29; removed from bark November 1 and exposed at once. Temperature used for both lots: +10°F.

Results:

No. 33

| Exposure Time | No. Larvae in Sample | Mortality % |
|---|---|---|
| Check | 25 | 8 |
| 15 min. | 25 | 12 |
| 30 min. | 25 | 20 |
| 45 min. | 25 | 48 |
| 1 hour | 22 | 50 |
| 1¼ hrs. | 25 | 64 |
| 1½ hrs. | 25 | 40 |
| 1¾ hrs. | 25 | 84 |
| 2 hrs. | 25 | 68 |
| 4 hrs. | 25 | 92 |

No. 34

| Exposure Time | No. Larvae in Sample | Mortality % |
|---|---|---|
| Check | 50 | 4 |
| 1 hour | 50 | 98 |
| 2 hours | 50 | 100 |
| 4 hours | 50 | 94 |
| 8 hours | 50 | 100 |
| 24 hours | 50 | 100 |

## Critical Temperatures in Relation to Host

Test No. 30
August 31, 1935

Material and Procedure: Brood in sugar pine and ponderosa pine from the central Sierra Field Station brought to Berkeley August 30, and placed in the laboratory. Larvae removed August 31 and exposed at once.

Results:

| Temperature | Host Sugar Pine: No. Larvae in Sample | Host Sugar Pine: Mortality % | Host Ponderosa Pine: No. Larvae in Sample | Host Ponderosa Pine: Mortality % |
|---|---|---|---|---|
| Check | 50 | 4 | 50 | 4 |
| 15° | 50 | 20 | 50 | 24 |
| 12½ | 50 | 56 | 50 | 22 |
| 10 | 50 | 88 | 50 | 56 |
| 7½ | 50 | 100 | 50 | 90 |
| 2 | 50 | 100 | 50 | 98 |

Test No. 32
October 15, 1935

Material and Procedure: Parent adults from Sierra lodgepole pine forced on sugar, ponderosa and lodgepole pine, brought in from the central Sierra field station ~~November~~ October 10 and stored out-of-doors until ~~November~~ October 15 when pent was used for a test ant the rest divided into lots for conditioning at 41°, 36°, and 20°.

Results:

| Temp. | Host Sugar Pine: No. Larvae in Sample | Host Sugar Pine: Mortality % | Host ~~Ponderosa Pine~~ Lodgepole pine: No. Larvae in Sample | Host ~~Ponderosa Pine~~ Lodgepole pine: Mortality % | Host ~~Lodgepole Pine~~ Ponderosa: No. Larvae in Sample | Host ~~Lodgepole Pine~~ Ponderosa: Mortality % |
|---|---|---|---|---|---|---|
| Check | 50 | 0 | 50 | 2 | 50 | 0 |
| 14 | 50 | 56 | 50 | 8 | 49 | 2 |
| 12½ | 50 | 0 | 50 | 14 | 50 | 4 |
| 10 | 49 | 100 | 50 | 10 | 50 | 28 |
| 7½ | 50 | 100 | 50 | 96 | 50 | 100 |
| 2 | 50 | 100 | 50 | 100 | 50 | 100 |

Test No. 38
December 9, 1935

Material and Procedure: Lodgepole strain in sugar pine and ponderosa pine and central Sierra-Peregoy lodgepole brood brought to Berkeley from the central Sierra field station December 8. Removed from logs December 9 and exposed at once.

Results:

| Temp. | Host - Sugar Pine: No. Larvae in Sample | Host - Sugar Pine: Mortality % | Host - Ponderosa P.: No. Larvae in Sample | Host - Ponderosa P.: Mortality % | Host - Lodgepole P.: No. Larvae in Sample | Host - Lodgepole P.: Mortality % |
|---|---|---|---|---|---|---|
| Check | 50 | 2 | 50 | 0 | 50 | 0 |
| 15° | 50 | 0 | 50 | 0 | | |
| 12½ | 50 | 96 | 50 | 6 | 50 | 14 |
| 10 | 49 | 88 | 50 | 4 | 50 | 4 |
| 7½ | 51 | 88 | 50 | 40 | 50 | 8 |
| 5 | 50 | 98 | 50 | 90 | 50 | 58 |
| 2½ | 50 | 98 | 50 | 100 | 50 | 58 |
| 0 | | | | | 50 | 76 |
| -2½ | | | | | 50 | 66 |
| -5 | | | | | 50 | 92 |
| -7½ | | | | | 50 | 100 |

Test No. 39
December 11, 1935

Material and Procedure: Sugar pine strain in the three hosts. Material brought to Berkeley December 8. Stored at 36° until December 11 when the larvae were removed from the logs and exposed at once.

Results:

| Temp. | Host - Sugar Pine: No. Larvae in Sample | Host - Sugar Pine: Mortality % | Host Ponderosa P.: No. Larvae in Sample | Host Ponderosa P.: Mortality % | Host - Lodgepole Pine: No. Larvae in Sample | Host - Lodgepole Pine: Mortality % |
|---|---|---|---|---|---|---|
| Check | 50 | 0 | 50 | 4 | 50 | 0 |
| 12½ | 50 | 2 | 50 | 2 | 50 | 0 |
| 10 | 50 | 6 | 50 | 2 | 50 | 4 |
| 7½ | 50 | 46 | 50 | 10 | 50 | 10 |
| 5 | 50 | 96 | 50 | 34 | 50 | 24 |
| 2½ | 50 | 100 | 48 | 50 | 50 | 36 |
| 0 | | | 50 | 72 | 50 | 72 |
| -2½ | | | 50 | 90 | 50 | 96 |

Relation of Previous Environmental Temperatures in Critical Range

Test No. 37

Material and Procedure: Same as No. 32. One group held at 41° and one at 20° for 35 days; the larvae removed from the logs and tested November 20. The third group was held at 36° for 40 days; removed from the bark and tested November 25.

**Results:**

| Temp. | Host: Sugar Pine — No. Larvae in Sample | Host: Sugar Pine — Mortality % | Host: Ponderosa Pine — No. Larvae in Sample | Host: Ponderosa Pine — Mortality % | Host: Lodgepole Pine — No. Larvae in Sample | Host: Lodgepole Pine — Mortality % |
|---|---|---|---|---|---|---|
| **41° Group** | | | | | | |
| Check | 25 | 4 | 50 | 0 | 50 | 0 |
| 10° | 25 | 72 | 50 | 4 | 50 | 10 |
| 7½ | | | 50 | 6 | 50 | 14 |
| 5 | 22 | 90 | 50 | 20 | 50 | 42 |
| 2½ | | | 50 | 58 | 50 | 60 |
| 0 | 26 | 100 | 50 | 66 | 50 | 58 |
| -2½ | | | 50 | 62 | 50 | 76 |
| **36° Group** | | | | | | |
| Check | 50 | 2 | 50 | 0 | 50 | 0 |
| 12½° | 50 | 56 | | | | |
| 10 | 50 | 58 | 50 | 0 | 50 | 0 |
| 7½ | 50 | 70 | 50 | 8 | 50 | 2 |
| 5 | 50 | 78 | 49 | 12 | 50 | 20 |
| 2½ | 49 | 82 | 50 | 34 | 50 | 10 |
| 0 | 50 | 90 | 50 | 36 | 50 | 34 |
| -2½ | | | 50 | 50 | 50 | 46 |
| -5 | | | 50 | 66 | 50 | 98 |
| -7½ | | | 50 | 100 | 50 | 100 |
| **20° Group** | | | | | | |
| Check | 25 | 8 | | | | |
| 10° | | | | | 24 | 4 |
| 7½ | 25 | 100 | 25 | 12 | | |
| 5 | | | 50 | 30 | 25 | 42 |
| 2½ | | | | | 50 | 74 |
| 0 | | | 14 | 73 | 25 | 80 |
| -2½ | | | | | 25 | 76 |

Critical Range in Relation to Locality

Test No. 38 (in part)
December 9, 1935

Material and Procedure: Material collected at Wocus Bay, Klamath Indian Reservation, Oregon, October 24, and brought directly to the other material stored in the central Sierra (October 28). Brought to Berkeley December 8 and tested with the other material given for No. 38. Compared with similar larvae from Peregoy - Central Sierra.

**Results:**

| Temperature | Central Sierra Region: No. Larvae in Sample | Central Sierra Region: Mortality % | Klamath Region: No. Larvae in Sample | Klamath Region: Mortality % |
|---|---|---|---|---|
| Check | 50 | 0 | 50 | 0 |
| 12½ | 50 | 14 | | |
| 10 | 50 | 4 | | |
| 7½ | 50 | 8 | 50 | 4 |
| 5 | 50 | 58 | | |
| 2½ | 50 | 58 | | |
| 0 | 50 | 76 | 50 | 8 |
| -2½ | 50 | 66 | 50 | 14 |
| -5 | 50 | 92 | 50 | 14 |
| -7½ | 50 | 100 | 50 | 40 |
| -10 | | | 50 | 74 |
| -12½ | | | 50 | 82 |